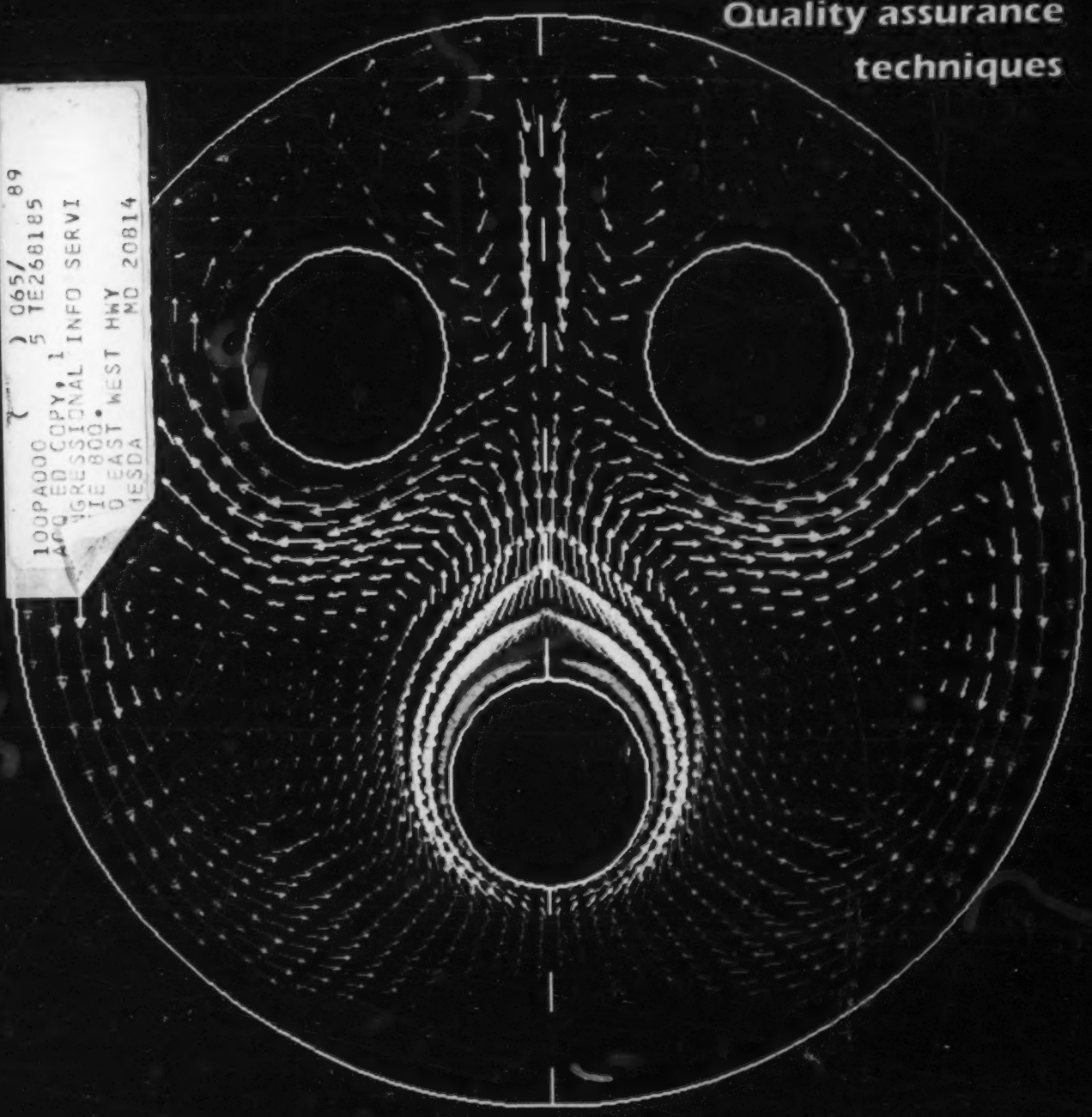
C1850-69
3/16/88

research & Development

MARCH 1988

A CAHNERS PUBLICATION

Quality assurance techniques



100PA000) 065/ 89
A 5 TE268185
ED COPY, 1
GRESSIONAL INFO SERVI
IE 800.
0 EAST WEST HWY
ESDA MD 20814

Annual salary survey and profile of the industry

SERVING THE $330-BILLION WORLDWIDE R&D INDUSTRY

Research & Development

The magazine with the R&D 100 Awards

EDITORIAL

9 **R&D: America's imperative**

DEPARTMENTS

15 **Innovative Notebook**
21 **Product Development**
25 **R&D Business**
29 **Research Trendletter**
31 **R/D News in Brief**
74 **Industry Events**
75 **Vacuum Technology**
89 **Equipment Literature File**
97 **New Products**
102 **R&D Product Center**
107 **Literature**
113 **Opinion Poll Results**
114 **Opinion Poll Questionnaire**
115 **Letters**
118 **Advertisers Index**
121 **Reader Service Card**

ABOUT THE COVER

Software for fluid dynamics separates problem definition, computations, and graphics. Creare's (Hanover, NH) "Fluent/BFC" can show velocity vectors, streamlines, and pressure and temperature controls.

NEWS

35 **R&D Business:** Select panel formed to boost U.S. R&D; Battelle Memorial Inst. consolidates two of its divisions

36 **Science policy:** NBS gets jurisdiction over data base access; U.S.-Soviets sign new scientific exchange agreement; British center will target applied science

37 **Computers:** Fractal geometry technique achieves compression ratios of 10,000:1

39 **Engineering:** Foreign-born engineers present opportunities, problems to U.S.; Physicists develop positron microscope

41 **Automotive R&D:** Fly-by-wire techniques being adapted for automobile controls

43 **Astronomy:** Strangeness reigns in the Pluto-Charon system; IR signals provide evidence for brown dwarfs; light detected from galaxies 17 billion light-years away

47 **Superconductivity:** British organize two high-temp research programs; Copper complexes combat radiation injuries

48 **Space:** Coffee-can-sized spacecraft

48 **Manufacturing:** High-precision die casting method developed; Coal-to-oil plant survives cutbacks in energy funds

ARTICLES

57 ***R&D* magazine's profile of the industry:** Robert R. Jones, editor, *R&D;* mixed bag of salaries in R&D; some workers do well.

62 **What's moving, and how does it affect your product?** K.E. Kasza and J.J. Oras, Argonne National Lab, and John Bagby, Eastman Kodak Co.; motion analysis.

70 **Build a test and measurement system in your computer:** L. McKee, Masscomp; program emulates lab instruments.

75 **A trapless leak detector:** William C. Worthington, Leybold Inficon Inc.; architectural changes and a new pump improve detector performance.

ABP BPA ABC

Cahners Publishing Company, A Division of Reed Publishing USA ☐ Specialized Business Magazines for Building & Construction ☐ Manufacturing ☐ Foodservice & Lodging ☐ Electronics & Computers ☐ Interior Design ☐ Printing ☐ Publishing ☐ Industrial Research & Technology ☐ Health Care ☐ Entertainment ☐ Specialized Consumer Magazines: American Baby ☐ Modern Bride.

For unexcelled expertise in the design and manufacture of

LAB FURNITURE, METAL CASEWORK and FUME HOODS

LAB OF THE YEAR AWARD

*Awarded to a Duralab Laboratory by Research & Development for 1984 and 1985.

SEE OUR CATALOG IN THOMCAT and SWEETS

DURALAB

features:

- Superior materials and craftsmanship
- Engineered for your Special requirements
- Approved budget

Exclusive use of nickel + lead-coated sheet steel with baked-on enamel finish to provide corrosion and acid resistance for the utmost in performance, durability and value.

Custom detailing includes concealed hinges, double-panel insulated doors and drawers with removable panels for easy cleaning and decontamination.

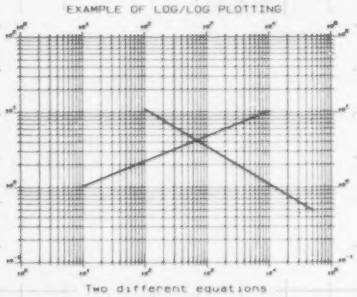
Call us to discuss your requirements.

DURALAB EQUIPMENT CORPORATION
107-23 Farragut Rd., Brooklyn, NY 11236
Phone: 718-649-9600
– SINCE 1952 –

TECH*GRAPH*PAD

Still trying to get Engineering & Scientific graphs from a Business program?

TECH* GRAPH* PAD



Easy-to-use IBM PC compatible graphing & plotting software for engineers & scientists. Compatible with Lotus 1-2-3 worksheets, other spreadsheets, and most data acquisition packages.

List Price: $275

- Curve Fitting • Smoothing
- Log/Log Plots • Labelling
- Multiple X-Y Axes
- Scale Control
- Many other technical features and functions

CALL

(617) 890-1812

binary engineering

100 Fifth Ave., Waltham, MA 02154

Research & Development

INTERNATIONAL JOURNAL OF RESEARCH, DEVELOPMENT, AND QUALITY ASSURANCE

Robert R. Jones
editor and editorial director

Gary L. Parr managing editor
Timothy G. Studt associate editor

Charles S. Derra news editor
Crystal Ann Taylor associate editor

Jan Swanson art director
Joan Cacioppo editorial assistant

H. Landon Thomas editorial consultant
Sandra Jean Brown editorial production manager

regular columnists: **Frederic B. Jueneman** and **Erwin A. Frand**

CORRESPONDENTS

Peter Gwynne, **Boston**
Ted Agres, **Washington**
Alan Radding, **New England**
Hal Tufty, **Washington**
Irwin Stambler, **Los Angeles**
England, Dennis Young
England, Edwin Haydon
Israel, Judy Carr
Japan, Thomas Murtha
Australia, William A. Scholes

EDITORIAL ADVISORY BOARD

Neil P. Ruzic, founder of *Industrial Research* Magazine, chairman
Dr. R.F. Bunshah, professor of engineering, Univ. of California, Los Angeles
Dr. E. Richard Cohen, distinguished fellow, Rockwell Intl. Science Center
Dr. Edward E. David Jr., president, EED Inc.
Dr. John Dempsey, vice president, technical operations, Bemis Co.
Dr. Humberto Fernandez-Moran, professor of biophysics, Univ. of Chicago
Dr. J.E. Goldman, former chief scientist, Corporate Research Centers, Xerox Corp.
Dr. James Hillier, former executive vice president and senior scientist, RCA Corp.
William G. Hyzer, consultant in engineering & applied science
Dr. J.C.R. Kelly Jr., Research & Development Center, Westinghouse Electric Corp.
Dr. Theodore H. Maiman, vice pres., advanced technology, TRW Electronics
Dr. Glenn A. Nesty, former vp, research; consultant, International Paper Co.
Dr. Dan W. Urry, director, Lab. of Molecular Biophysics, Univ. of Alabama

Laboratory of the Year Award Program Adviser
Fred L. Bernheim, FARA, Bernheim • Kahn Ltd. Architects

publisher: **Timothy M. Kelly**

consultant: **C.J. Mosbacher**
business manager: **Patricia Miller**
advertising sales assistant: **Marylyn Dorsett**
advertising production: **Judy Rexford**
I•R 100 coordinator: **Tina Lentz**
marketing research: **Susan Humes**
circulation manager: **Ruben Natal**
comptroller: **William J. Stanners**
reprints (312/635-8800): **Frank Pruzina**

Editorial, executive, and sales offices: Box 5080, Des Plaines, IL 60017-5080; USA
Telephone 312/635-8800

Research & Development (ISSN 0746-9179) is published monthly except semi-monthly in March by The Cahners Publishing Company, A Division of Reed Publishing USA, 275 Washington St., Newton, MA 02158-1630. Terrence M. McDermott, President; Robert T. Brawn, Group Vice President; Jerry D. Neth, Vice President/Publishing Operations; J.J. Walsh, Financial Vice President/Magazine Division; Thomas J. Dellamaria, Vice President/Production and Manufacturing.; Timothy M. Kelly, Vice President and Publisher; Neil P. Ruzic, founder of *Industrial Research*.

Circulation Records are maintained at Cahners Publishing Company, 44 Cook St., Denver, CO 80206-5191 (Phone: 303/388-4511). **Circulation:** More than 115,000 copies distributed. Second-class postage paid at Denver, CO 80206-5191, and at additional mailing offices. **Postmaster:** Send address corrections to *Research & Development* at our Denver address.

Subscriptions: Annual subscription rates for non-qualified people: USA, 1 yr $40; Canada, Mexico, and foreign via surface mail, 1 yr $55; foreign via air mail 1 yr $100. Except for special issues where-price changes are indicated, single copies of regular issues are available for $10. Please address all subscription mail to *Research & Development*, 44 Cook St., Denver, CO 80206-5191. Include zip code and—for change of address—copy of old label.

Research & Development copyright 1988 by Reed Publishing USA; Saul Goldweitz, Chairman; Ronald G. Segel, President and Chief Executive Officer; Robert L. Krakoff, Executive Vice President; William M. Platt, Senior Vice President.

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage retrieval system, without written permission of the copyright owner. Prices for bulk reprints of articles available on request. Copies of back issues are available from University Microfilm, 300 N. Zeeb Rd., Ann Arbor, MI 48106, and on microfiche from Micro-Photo Div., Bell & Howell, Old Mansfield Rd., Wooster, OH 44691. Research & Development articles are indexed in Engineering Index, Current Contents, and the New York Times Information Bank.

Robert R. Jones, Editor, *R&D*

R&D's mixed salary bag provides well for workers in some disciplines

Many factors, including early retirement, job changes, mergers, start-ups, and modest pay raises, led to overall gains for the categories of metallurgists, geologists, and biologists, and downers for mathematicians and ceramists, while some individuals moved against the trends.

THE R&D salary bell is going flat. This is not to say that it makes a sour note. (In fact, there are many people among this year's nearly 1,900 *R&D* Opinion Poll respondents who find it especially attractive this way.)

It's just that in any of the recent years a chart of respondents' salaries against the number of persons receiving each salary level would have produced a fairly nice bell curve, a Gaussian distribution, with a distinct peak and almost-matching halves. And each year, as general salary levels were increased to keep even with inflation, the essentially unchanged bell shape moved a little to the right, toward the higher income side of the chart.

Now things are changing. Careful study of the files for this survey shows that, in truth, the shape of the curve has undulated over the years, with this current flattening starting in 1983. But this change was not particularly noticeable until this year's survey.

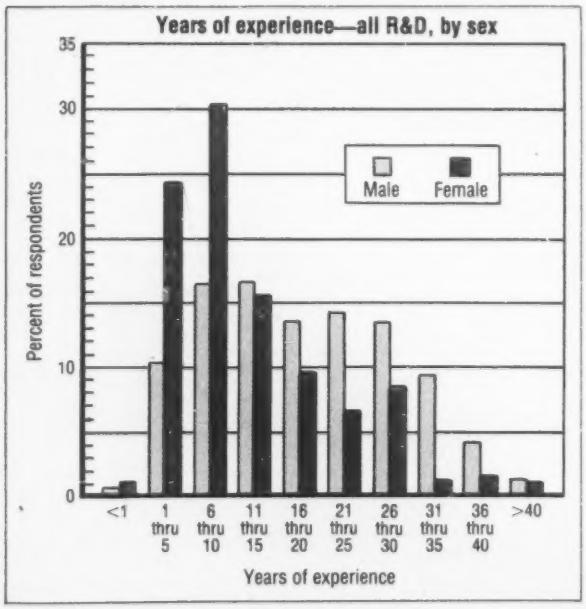
The result is that, for the third year in a row, the peak of the curve has not shifted to left or right. For four consecutive years the salary range of $40,000 through $44,999 has held each year's largest single group of respondents. But the size of that group has dropped from 16.5% of respondents in 1986 to 14.5 this year. The heighth of the plotted peak and the peak's shoulders also are lower.

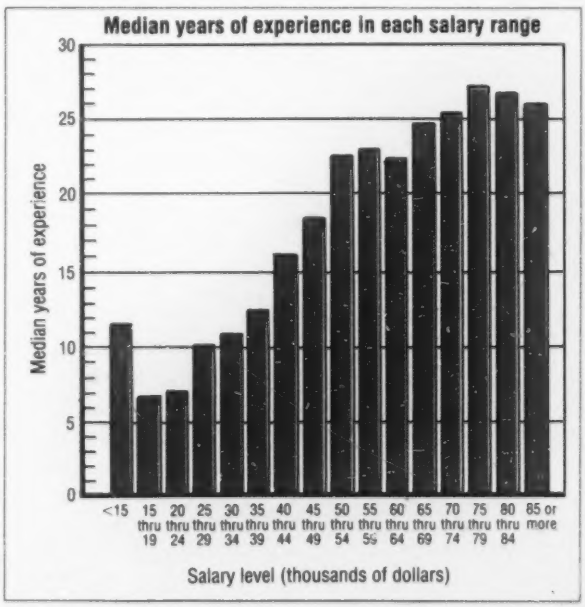
All of those respondents who do not fit under the lower peak now will be found along a stretched out right-hand slope (higher income portion) of the curve.

To be specific, in 1986 60.8% of workers in research, development, and quality assurance who responded to our survey fell into the salary ranges from $35,000 through $59,999. This year, that figure is down to 58.7, a 3.5% decline.

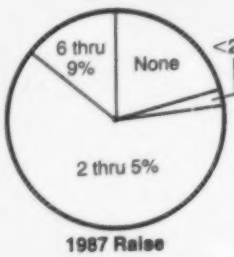
Over the same period, the number in the range above $59,999 has increased from 8.7% to 14.4, a gain of 65% in the affluent portion of the distribution. This has occurred despite the fact that the percentage earning $80,000 per year or more is the same this year as it was last year.

While 46% of respondents received salary in-

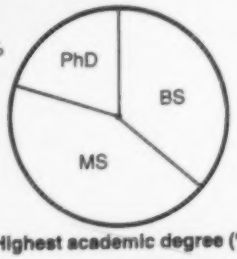




Aeronautical engineer



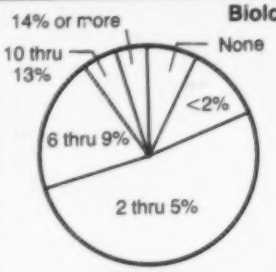
1987 Raise



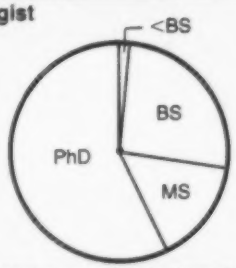
Highest academic degree (%)

1987 salary range:	<$15,000 = 0.0% >$85,000 = 0.0%	Median $52,917
Years with present employer:	< 1 yr = 0.0% >36 yr = 3.4%	Median 17.0 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 3.6%	Median 49.25 yr
Years of experience:	< 1 yr = 3.4% >40 yr = 6.9%	Median 22.58 yr

Biologist



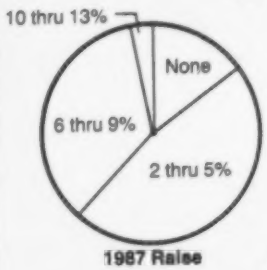
1987 Raise



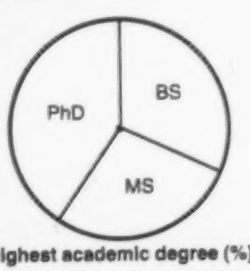
Highest academic degree (%)

1987 salary range:	<$15,000 = 2.2% >$85,000 = 0.0%	Median $40,625
Years with present employer:	< 1 yr = 1.1% >36 yr = 1.1%	Median 9.5 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0%	Median 40.92 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0%	Median 14.81 yr

Ceramist



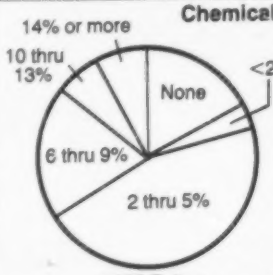
1987 Raise



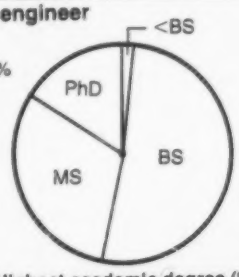
Highest academic degree (%)

1987 salary range:	<$15,000 = 0.0% >$85,000 = 0.0%	Median $43,750
Years with present employer:	< 1 yr = 0.0% >36 yr = 0.0%	Median 8.6 yr
Age of respondents:	<26 yr = 3.4% >65 yr = 0.0%	Median 38.42 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0%	Median 14.25 yr

Chemical engineer



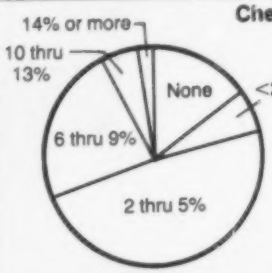
1987 Raise



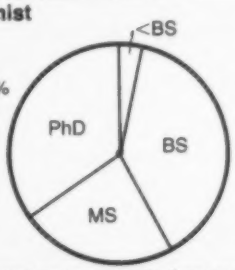
Highest academic degree (%)

1987 salary range:	<$15,000 = 5.3% >$85,000 = 0.0%	Median $45,109
Years with present employer:	< 1 yr = 3.6% >36 yr = 0.6%	Median 8.16 yr
Age of respondents:	<26 yr = 6.5% >65 yr = 0.0%	Median 39.63 yr
Years of experience:	< 1 yr = 1.8% >40 yr = 0.6%	Median 14.07 yr

Chemist



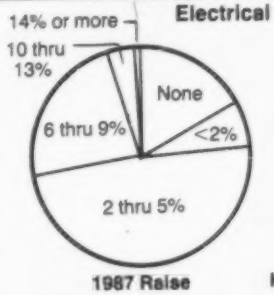
1987 Raise



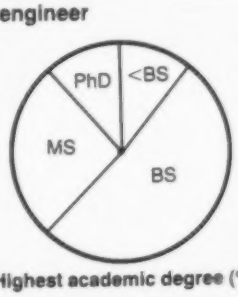
Highest academic degree (%)

1987 salary range:	<$15,000 = 1.3% >$85,000 = 1.0%	Median $42,113
Years with present employer:	< 1 yr = 5.0% >36 yr = 0.3%	Median 9.83 yr
Age of respondents:	<26 yr = 2.2% >65 yr = 1.4%	Median 41.97 yr
Years of experience:	< 1 yr = 0.3% >40 yr = 1.7%	Median 16.4 yr

Electrical engineer



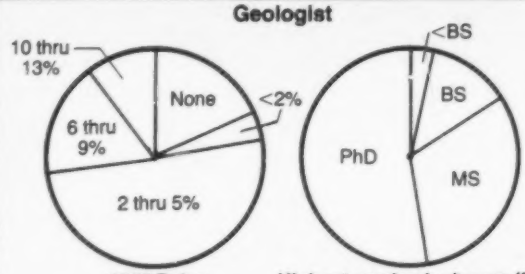
1987 Raise



Highest academic degree (%)

1987 salary range:	<$15,000 = 1.3% >$85,000 = 0.6%	Median $45,476
Years with present employer:	< 1 yr = 6.2% >36 yr = 1.9%	Median 9.02 yr
Age of respondents:	<26 yr = 3.1% >65 yr = 1.9%	Median 45.2 yr
Years of experience:	< 1 yr = 0.6% >40 yr = 1.9%	Median 21.45 yr

Geologist



1987 Raise — Highest academic degree (%)

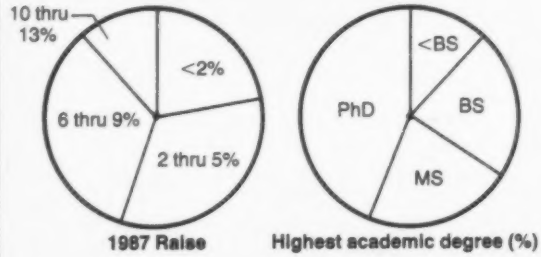
1987 salary range:	<$15,000 = 6.1% >$85,000 = 3.0%	**Median** $48,750
Years with present employer:	< 1 yr = 6.1% >36 yr = 0.0%	**Median** 6.71 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0%	**Median** 44.0 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0%	**Median** 10.31 yr

Industrial engineer

1987 Raise — Highest academic degree (%)

1987 salary range:	<$15,000 = 0.0% >$85,000 = 0.0%	**Median** $37,500
Years with present employer:	< 1 yr = 0.0% >36 yr = 5.6%	**Median** 8.75 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0%	**Median** 45.5 yr
Years of experience:	< 1 yr = 5.6% >40 yr = 0.0%	**Median** 18.83 yr

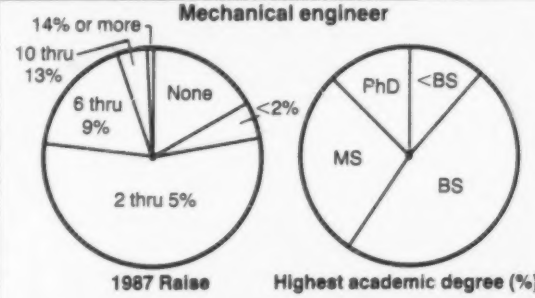
Mathematician



1987 Raise — Highest academic degree (%)

1987 salary range:	<$15,000 = 0.0% >$85,000 = 0.0%	**Median** $41,250
Years with present employer:	< 1 yr = 0.0% >36 yr = 0.0%	**Median** 11.75 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0%	**Median** 48.0 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0%	**Median** 24.25 yr

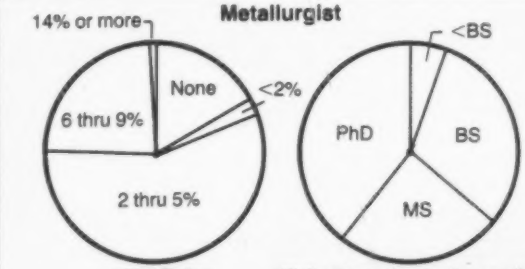
Mechanical engineer



1987 Raise — Highest academic degree (%)

1987 salary range:	<$15,000 = 1.9% >$85,000 = 0.5%	**Median** $44,828
Years with present employer:	< 1 yr = 4.3% >36 yr = 1.0%	**Median** 9.11 yr
Age of respondents:	<26 yr = 2.9% >65 yr = 0.0%	**Median** 43.25 yr
Years of experience:	< 1 yr = 1.0% >40 yr = 1.4%	**Median** 18.33 yr

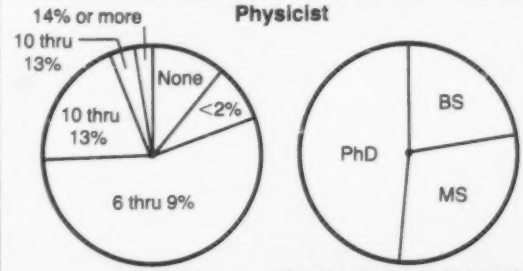
Metallurgist



1987 Raise — Highest academic degree (%)

1987 salary range:	<$15,000 = 2.9% >$85,000 = 0.0%	**Median** $49,375
Years with present employer:	< 1 yr = 2.9% >36 yr = 0.0%	**Median** 9.04 yr
Age of respondents:	<26 yr = 4.3% >65 yr = 4.3%	**Median** 43.77 yr
Years of experience:	< 1 yr = 1.4% >40 yr = 2.9%	**Median** 18.0 yr

Physicist



1987 Raise — Highest academic degree (%)

1987 salary range:	<$15,000 = 2.1% >$85,000 = 1.4%	**Median** $47,955
Years with present employer:	< 1 yr = 1.4% >36 yr = 0.0%	**Median** 9.5 yr
Age of respondents:	<26 yr = 0.7% >65 yr = 0.7%	**Median** 44.11 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.7%	**Median** 18.1 yr

creases last year (affecting income this year) that were larger than inflation, the median income is little changed from last year's (up 0.4%). This suggests that substantial numbers of higher-paid individuals have left the field through—for example—early retirement. Other parts of this study lead to the same conclusion.

Increases in rate of pay*

Amount of increase	1988	1987	1986	1985	1984	1983
	% of respondents					
None	14.5	16.5	11.3	9.3	16.3	14.7
Less than 2%	6.3	4.3	3.6	2.9	2.1	1.9
2 through 5%	49.8	39.2	37.1	36.6	26.9	15.9
6 through 9%	21.7	30.8	36.3	37.6	38.9	34.2
10 through 13%	4.7	6.0	8.3	10.1	11.5	25.1
14% or more	3.0	3.2	3.3	3.6	4.4	8.3
Ahead of inflation	46.0	79.2	60.1	63.3	54.8	33.4

* Granted in preceding year for year shown

The table shows the distribution and size ranges for salary increases in research, development, and quality assurance from 1983, when inflation was high, to date. Despite the much lower rate of inflation in 1987, the portion of respondents who received salary increases greater than the amount of inflation is at the lowest level since 1983.

Some disciplines show strong indications of changing patterns of employment. Median years of experience can shift for a variety of reasons, but perhaps the fastest effect comes as a result of changes in hiring and retirement practices. Of particular interest this year are the chemical engineers whose median years of experience dropped from 16.0 to 14.1, and the mechanical engineers who dropped from 20.3 to 18.3.

For both disciplines, the percentages of those who have less than one year's experience are up and the percentages having more than 40 years' experience are down, suggesting that early retirees may be being replaced by employes who are new to the fields.

This is supported, too, as the median ages are lower now in these disciplines than they were last year, with chemical engineers down from 41.3 to 39.6 and mechanical engineers down from 45.4 to 43.2.

That the industry is in flux is further borne out in the rankings of disciplines by median salaries. At no other time in recent years has there been so much change in rankings over one year. Five disciplines suffered declines in their median salaries from 1987 to 1988, and all but one of these lost rank in the table. Only one discipline, metallurgists, had a negative in the percent of increase column last year, and they were the third-highest gainer this year.

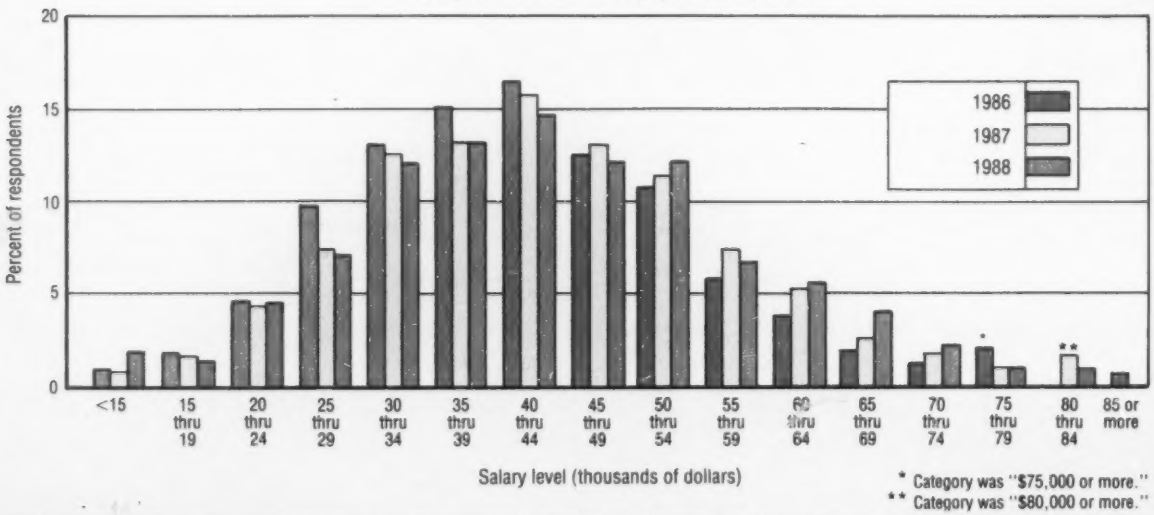
Rankings for disciplines by median salaries

Rank 1988	Rank 1987	Discipline	Median salary 1988	Median salary 1987	% increase
1	1	Aero. Engr.	$52,917	$50,278	5.3
2	4	Metallurgist	49,375	46,625	5.9
3	7	Geologist	48,750	45,714	6.6
4	2	Physicist	47,955	48,431	−1.0
5	9	Elec. Engr.	45,476	44,308	2.6
6	6	Chem. Engr.	45,109	45,865	−1.6
7	8	Mech. Engr.	44,828	44,385	1.0
8	3	Ceramist	43,750	47,812	−9.3
9	10	Chemist	42,113	41,860	0.6
10	5	Mathematician	41,250	46,250	−10.8
11	12	Biologist	40,625	38,100	6.6
12	11	Indust. Engr.	37,500	38,889	−3.6

Despite the shifts in discipline rankings, the net movement is (slightly) upward, and the R&D industry remains an attractive demographic market. Scientists and engineers working in research and development will draw a collective paycheck this year exceeding $26.04 billion. This is up from $25.9 billion last year and $24.5 billion in 1986.

In the second part of this annual industry profile we will look into the implications of some of the above conclusions and also report on the money value of advanced degrees in this somewhat topsy-turvy salary situation. We also will examine relative pay scales in research and development for men and women, and the advantages—in salary terms—for jobs in government, universities, and industry. R&D

Salary levels for all R&D (3 years compared)



OPNION POLL RESULTS

Surprise! Staff meetings are worth it

IN THE JULY 1987 issue of *Research & Development* we asked your opinions of staff meetings, fully expecting almost unanimous dislike of meetings regardless of length or purpose. The responses we received from 1,062 readers suggest that staff meetings are needed and, for the most part, are worthwhile.

By far the majority of the meetings are held to present progress reports. Most meetings also last about an hour and are informal. More than 60% of the respondents also feel that the number of meetings they now have is adequate. Results of the survey follow:

1. *How often do you have staff meetings?*
   a. Weekly 37%
   b. Monthly 19
   c. When needed 32
   d. Rarely, if ever 11

2. *In general, are the meetings worthwhile?*
   a. Yes 46%
   b. No 13
   c. Sometimes 41

3. *How long do your meetings last?*
   a. More than an hour 43%
   b. 60 min. at most 46
   c. 30 min. or less 11

4. *Are the meetings based on a previously distributed agenda?*
   a. Yes 20%
   b. No 50
   c. Sometimes 29

5. *What usually is the main purpose for having the meetings that you attend?*
   a. Scheduling and job assignments 21%
   b. Progress reports, research updating 66
   c. Planning for future research 6
   d. Brainstorming/"blue sky" discussions 5

6. *Would you consider the meetings that you attend to be formal or informal in format?*
   a. Formal 10%
   b. Informal 89

7. *Does someone keep minutes or make a report of what is discussed at the meetings?*
   a. Yes 37%
   b. No 63

8. *How do you feel about the number of meetings that is scheduled for your staff?*
   a. Would like to have more meetings 18%
   b. Would like to have fewer meetings 20
   c. The number of meetings we have now is adequate 61

WANT TO MEASURE MICRO-OHMS, MILLI-OHMS, OR EVEN NANO-OHMS?

We have high-performance, low-cost solutions for any low-resistance measurement problem.

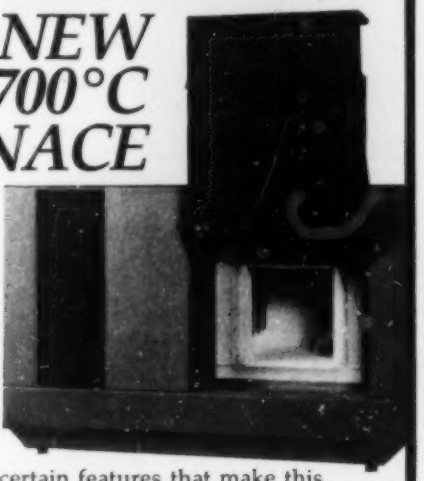
- The rugged, easy-to-use, Model 510A Digital Micro-ohmmeter provides honest 1 micro-ohm resolution, 4½ digits, and a basic accuracy of 0.02%.
- Three measurement modes: SWITCHED DC cancels thermal errors. CONSTANT DC for inductive components. PULSED MODE for thermally sensitive devices.
- Dry-Circuit test mode, rugged 4-terminal Kelvin clips, and BCD outputs included.
- Accessories for every application including battery-pack, limits-comparator, computer interface, and resolution to 10 nano-ohms.

Money-back Guarantee: Try the 510A free for 30 days.

Cambridge Technology, Inc.
23 ELM STREET, WATERTOWN, MA 02172 U.S.A. (617) 923-1181

CIRCLE 205 ON INQUIRY CARD

THE NEW 1700°C FURNACE



A close look at Thermolyne's new high temp furnace reveals certain features that make this furnace safer, more efficient and easier to use in a variety of laboratory and research applications.

- Heat-up time — 40 min. to 1700°C
- Two chamber sizes: 6"H x 6"W x 6"D and 10"H x 10"W x 10"D
- Select either single set point or programmable temperature controller
- Computer interface capability available via RS232 port

Available through your local lab distributor or contact:

Thermolyne 800-553-0039
SUBSIDIARY OF SYBRON
2555 Kerper Blvd. • Dubuque, IA 52001 • (319) 556-2241

CIRCLE 206 ON INQUIRY CARD